GM's Black Box
http://www.frankhunt.com/FRANK/corvette/articles/black_box/AirBag_Sensor.html

The "BLACK BOX"
Well folks, It's Really Silver!
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Here are the answers to the hundreds of telephone, snail mail and e-mail questions and opinions I've received as well as those posted on the various nets. To put everyone's mind at ease, we will review its purpose and take an in-depth look at its design.

Because of my interest stemming from the news media and the huge number of inquires, I approached certain very reliable individuals at Chevrolet and GM for an official on the record statement and relative data regarding the "black box?

First, It must be stated that it is not black. Its silver and the name "black box" originated from the airlines' use of "flight data recorders" which are often referred to as the "black box", mostly by the media.

The real name of this box is "Sensing Diagnostic Module" and its true and actual purpose is to record automotive crash data. I began my research with Bob Tritolsky of Chevy Communications, then Terry Rhadigan of GM Safety & Legal Media Relations who graciously provided a rather complete review of the system during a lengthy interview. He, however, gave most of the credit to Thomas Mercer and Keith Schultz of GM and Augustus Chidester and John Hinch of the National Highway Traffic Safety Administration (NHTSA) due to the many statements he read from an official study/analysis "paper" prepared by them. Moreover, he furnished me with a copy of that very paper and from it, much will be repeated for reference purposes in order to provide a thorough understanding of the entire 5DM system. Before we begin with those statements, it is important to note that other sources (friends) were contacted to provide additional elements of which GM didn't have as yet for this review. Larry Liposky, Director of New Business Development of Helm, Inc. (the officially authorized publisher of Service and Owner's Manuals) provided the line art illustrations and Pete Eubanks of MTI (see from "Track To Track" in this issue) provided the photographs of the module and its label (removed specifically for photographic purposes) from a C5.

To continue on, I asked Terry to furnish an official GM statement. Without hesitation or limitations regarding the information, he stated that what he is providing about the event data recorders on select 1999 passenger cars, is to be attributed to Bob Lange, the Engineering Director, Product Safety.

"In order to improve automotive safety through better real world data and testing materials, GM introduced enhancements to its vehicles which will enable researchers to retrieve pre-crash data from a vehicle's air bag Sensing and Diagnostic Module (SDM). The enhanced SDM will be installed on the 1999 model year Buick Century, Park Avenue, Regal; Cadillac Eldorado, Deville, Seville; Pontiac Firebird and Chevrolet Camero and Corvette vehicles.

GM's announcement is, in part, a response to last year's National Transportation Safety Board's (NTSB) recommendation to the National Highway Traffic Safety Administration (NHTSA) and the automotive industry to gather better information on crash pulses and other crash parameters from actual crashes, while utilizing current augmented crash sensing and recording devices.'

The NTSB demonstrated the usefulness of event data recorders or "black boxes" in understanding and preventing airline crashes. While GM's event data recorders are less sophisticated than those in aircraft; these enhancements represent a new opportunity to improve new vehicle safety. Researchers will have fresh insight into how drivers are reacting to hazards and interacting with their vehicles. This information can help provide critical insight to crashes, resultant injury patterns and may even-

This is the actual magnified (for better readability) Cautionlabel affixed to the module previously shown. It clearly indicates that it is an air bag sensor and shows the OEM P/N.Truly lead to improved crash worthiness designs.

Crash construction will be easier and more precise. Defect investigations and rule making can also benefit by having a more objective and scientific basis."

Next, asked Terry to comment about the system's prior to 1999 model year use and again, he was very open about the subject.

"For several years, GM vehicles were equipped with an SDM that records information about the air bags and related systems. Existing SDM's record information about the readiness of the air bag systems, when the sensors are activated and driver's safety belt usage at deployment or in near-deployment crashes.

GM research engineers used advancements in technology to connect the SDM to a local area network within the vehicle. This allowed the SDM to literally talk to the other components and sensors in the vehicle without adding hardware. The additional parameters the enhanced SDM records are vehicle speed, throttle position, engine RPM and brake use.

In the event of a crash that we hope never happens, the SDM senses any frontal impact and determines when to deploy the air bags. The signal to deploy the air bags is also a signal to store data on the four additional parameters taken during the previous five seconds. The enhanced SDM stores the vehicle speed, engine speed, throttle position and brake use, as I already mentioned, at one second intervals just priority the crash event. The recorded data is available for retrieval and evaluation even if the battery has been disconnected or the SDM box has been unplugged.

Ultimately, the enhanced SDM stores information whenever a severe impact causes the air bags to deploy, or under certain circumstances, it may also store data for a near-deployment event. The data storage is activated by the air bags system during frontal impacts. An impact roughly 12 miles per hour or greater into a rigid barrier will trigger the data collection. Another example that would trigger the data collection is a crash into a parked car at 24 to 30 miles per hour.

This will only be an active tool in frontal collections. Frontal crashes are still the major cause of death or serious injury in passenger car collisions."

Now let's review the "Recording Automotive Crash Event Data" "paper' I received directly from Terry. It is very lengthy and to a degree. Certain parts are a repetition of information previously presented.

"INTRODUCTION: The National Transportation Safety Board recommended that automobile manufacturers and the National Highway Traffic Safety Administration work cooperatively to gather information on automotive crashes using on-board collision sensing and recording devices.

Since 1974, General Motors' air bag equipped production vehicles have recorded air bag status and crash severity data for impacts that caused a deployment. Many of these systems also recorded data during 'near-deployment' events, i.e., impacts that are not severe enough to deploy the air bag(s). GM design engineers used this information to improve the performance of air bag sensing devices and NHTSA researchers used it to help understand the field performance of alternate air bag system designs.

Beginning with the 1999 model year, the capability to record pre-crash vehicle speed, engine RPM, throttle position and switch on/off status has been added to some GM vehicles. This paper discusses the evolution and contents of the current GM event data recording capability, how other researchers working to develop a safer highway transportation system might acquire and utilize the information, and the status of the NHTSA Motor Vehicle Safety Research Advisory Committee's Event Data Recorder Working Group effort to develop a uniform approach to recording such data.

EVOLUTION OF GM WENT DATA RECORDING: GM introduced the first regular production driver/passenger air bag systems as an option in selected 1974 production vehicles. They incorporated electromechanical g-level sensors, a diagnostic circuit that continually monitored the readiness of the air bag control circuits and an instrument panel Readiness and

Warning lamp that illuminated if a malfunction was detected. The data recording feature utilized fuses to indicate when a deployment command was given and stored the approximate time the vehicle was operated with the warning lamp illuminated.

During 1990, a more complex Diagnostic and Energy Reserve Module (DERM) was introduced with the added capability to record closure times for both the arming and discriminating sensors as well as any fault codes present at the time of deployment.

During 1992, GM installed sophisticated crash-data recorders on 70 Indy race cars while impractical for high volume production, these recorders provided new information on human body tolerance to impact that can help improve both passenger vehicle occupant and race car driver safety. As an example, the data demonstrated that well restrained, healthy male race car drivers survive impacts involving a velocity change of more than 60 MPH and producing more than 100 gs of vehicle deceleration. Such information will be helpful to biomechanics refining their understanding of human injury potential.

Enlarged view of pre-assembled dash unit yet to be installed. Arrows indicate the brackets where the SDM shelf will be positioned.

Changes in race car design have also been made using data obtained from the on-board recording capability. Specifically it was observed that a substantial deceleration pulse occurred when the vehicle's differential 'bottomed out' during rear impact crashes. Knowing this, a simple, lightweight impact attenuator was designed that, in combination with improved head padding, is believed to have substantially reduced the number of serious driver injuries during the 1998 racing season.

For the 1994 model year, the multiple electromechanical switches previously used for crash sensing were replaced by the combination of a single solid state analog accelerometer and a computer algorithm integrated in a Sensing & Diagnostic Module (SDM)." This folks, IS the black box.

The SDM also computed and stored the change in longitudinal vehicle velocity (Delta-V) during the impact to provide an estimate of crash severity. This feature allowed GM engineers to obtain restraint system performance data when a vehicle was involved in a deployment event or experienced an impact related change in longitudinal velocity, but did not command deployment (i.e. near-deployment event).

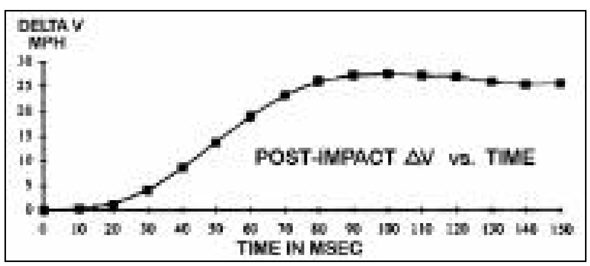
The SDM also added the capability to record the status of a driver's belt switch (buckled or unbuckled) for deployment and near-deployment events.

TECHNICAL DESCRIPTION OF THEEVENT DATA RECORDING PROCESS: The crash sensing algorithm used in 1999 model year GM vehicles decides whether to deploy the air bags based on calibration values stored in the SDM reflecting that vehicle model's response to a variety of impact conditions. This predictive algorithm must make air bag deployment decisions typically within 15 to 50 milliseconds (.015 to .050 sec) after impact.

The SDM's longitudinal accelerometer is low-pass filtered at approximately 40 Hz to protect against aliasing before being input to the micro controller. The typical SDM contains 32k bytes of ROM for program code, 512 bytes of RAM and 512 bytes of EEPROM. Every 312 microseconds, the algorithm samples the accelerometer using and A/D converter (ADC) and when two successive samples exceed about 2 gs of acceleration, the algorithm is activated (algorithm enable).

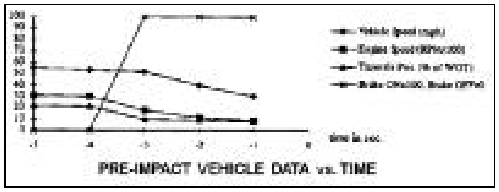
Because of EEPROM space limitations, the SDM does not record the actual deceleration data. However, the frequency content of the crash pulse that is of interest to crash reconstructionists typically does not exceed 60 Hz and the crash pulse can therefore, be well represented by low frequency velocity change data (Delta-V). The SDM computes Delta-V by integrating the average of four 312 microseconds acceleration samples and stores them at 10 millisecond increments in RAM.

The following chart shows the Delta-V values for a representative moderately high severity crash at each 10 MSEC point with a smooth curve drawn through them.



Several other sensors provide driver seat belt status, vehicle speed, engine RPM, brake on/off status and throttle position. The driver seat belt switch signal is typically input into the SDM while the remaining sensors are monitored by one or more other electronic modules that broadcast their data onto the serial data bus. If there is an air bag deployment or a near-deployment crash, the last five seconds of data immediately preceding algorithm enable are stored in EEPROM. All stored data can be later recovered using a laptop PC equipped with appropriate software and interface hardware.

The following chart shows how the pre-impact sensor data would appear when downloaded. To understand this, it requires some knowledge of the serial data bus and the SDM's role. First, the serial data bus operates as a 'contention' type of bus. Electronic modules transmit data based on a 'send on change' design. For example, when engine speed changes by at least 32 RPM, the engine micro controller broadcasts the new RPM value on the serial bus.



PRE-IMPACT VEHICLE DATA vs. TIME

Once each second, the SDM takes the most recent sensor data values and stores them in a recirculating buffer (RAM), one storage location for each parameter for a total of five seconds. When the air bag sensing system algorithm 'enables' shortly after impact, buffer refreshing is suspended. Note that algorithm enable is asynchronous with the transmission of vehicle speed and other data. Hence, the data on the bus can be skewed in time from the crash by as much as one second.

The molecules that broadcast the sensor data (engine RPM, brake status, etc.) also diagnose the sensors for faults and indicate the data's validity to the 5DM. The bus is also constructed so failures of the serial link are detected by the SDM. At the time of deployment, the state of the driver's seat belt switch, the manual cutoff passenger air bag switch (if equipped), warning lamp state and time to deployment are temporarily stored in RAM. The critical parameter values used to make the deployment decision are also captured in RAM.

When 150 MSEC have elapsed from algorithm enable, the data stored in RAM are transferred to the EEPROM. It requires about 0.7 seconds to permanently record all information. Once a deployment record is written, the data is frozen in EEPROM and cannot be erased, altered, or cleared by service or crash investigation personnel.

The recording of near-deployment data includes the pre-impact vehicle speed, engine RPM, etc. The criteria used to determine whether a near-deployment event is stored in EEPROM is based on the maximum Delta-V observed during the event. If this maximum Delta-V is larger than the previously recorded Delta-V, the new near-deployment event is stored along with the corresponding pre-impact data. The near-deployment record is cleared after 250 ignition cycles. This is equivalent to an average of about 60 days of driving.

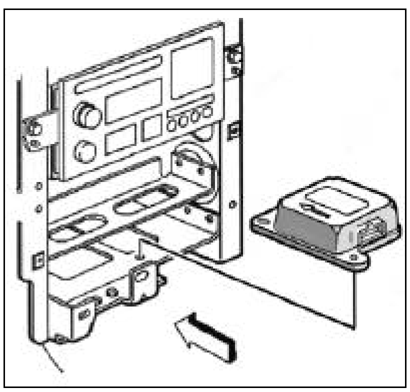
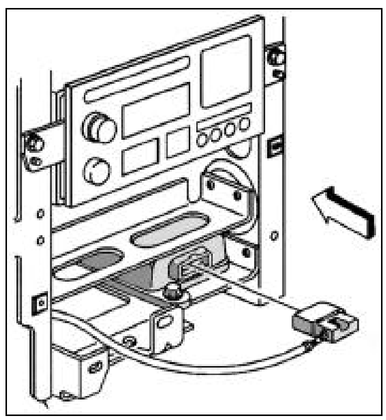
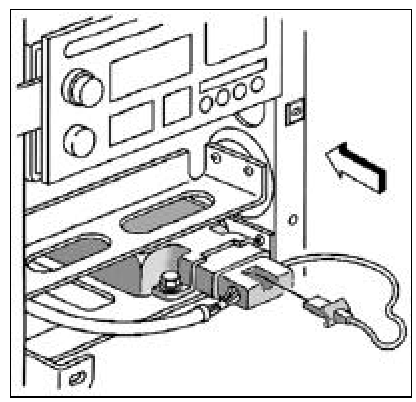
Each time the algorithm is enabled and no deployment is commanded, the SDM compares the maximum Delta-V previously stored with the maximum Delta-V of this new event to decide whether to update the near-deployment data.

DATA ACCURACY, LIMITATIONS & VALIDATION: Event information consists of discrete and variable data. Discrete data includes brake switch status, manual passenger air bag cutoff switch position and driver seat belt switch status. Variable data includes the analog acceleration information from which Delta-V is computed, vehicle speed, engine RPM and throttle position.

There are three main sources of error in estimating Delta-V. One error comes from the tolerance of the components of the 5DM and the micro controller. The hardware elements include the accelerometer, the analog-to-digital converter CADC), low pass filter and signal conditioning. The accelerometer and ADC contribute the largest portion of the total system error Accelerometer accuracy is about 8% of full scale which equates to a Delta-V error of~+ 4.5 MPH. ADC error is about 0.25 gs, not including quantization noise. Over a 150 MSEC recording period, the ADC contributes a maximum of 0.8 MPH.

The second Delta-V error is due to integer-based arithmetic and representing Delta-V using single data bytes. For a 56 MPH full-scale value, 7 bits (plus a sign bit) equates to a precision of 0.438 MPH.

The third error source that applies only to 1999 model vehicles, results from the crash sensing algorithm continuously applying a is bias acceleration in the opposite direction to that seen in frontal impacts. This bias prevents inadvertent air bag deployments resulting from Delta-V accumulation when driving on rough roads and contributes an underestimation error of 3.3 MPH at the end of 150 MSEC

GM is in the process of updating source. In the meantime, the downloading tool will utilize software to compensate for the bias.

Another less predictable error comes from the potential for losing electrical power during the crash. While the SDM maintains the defacto industry standard energy reserve for air bag deployment, the reserve is insufficient to guarantee that all event data will be recorded in every crash. However, if it is not recorded, the SDM indicates this condition in the data record General Motors historically verified it's software to eliminate this error.

Proper SDM operations using component tests and laboratory simulations, Shock (thruster) tests were conducted to verify crash recorder operation in deployment and near-deployment events. Crash tests were also conducted and the event data verified when the vehicle was propelled by a tow system. Additionally, a crash test was conducted with the engine running at partial throttle before impact with a fixed barrier to further verify pre-impact data recording capability All data recorded prior to and during the crash were within defined error limits.

GM and the NHTSA have also cooperated in comparing event data and laboratory instrumentation for crashes conducted by NHTSA contractors for regulatory compliance and consumer information purposes.

To date, the results have been satisfactory and will not be further discussed here since the work as yet, is not complete. Information from actual field events covering a variety of impact types are expected to confirm proper operation of the recording feature and offer insights about improvements which could aid crash investigators

USES OF EVENT DATA RECORDER INFORMATION: There are three categories of uses for the data that can be obtained from the on-board data recording capability.

One is improving air bag sensing systems such as sensor calibration adjustments to desensitize the SDM's response to relatively rare events such as those produced by small rocks or debris striking the underside of the vehicle with high impulsive energy.

Another is for the improvement of roadway design that would include side slopes, ditches, and safety fences located along the roadside (e.g. guard rails, crash cushions, light poles, breakaway signs, etc.). It can also be used to develop appropriate design tests and standards, thus making the objective data about crashes (pre-crash vehicle speed, brake use, crash severity, etc.) an invaluable tool.

The third category is meaningful motor vehicle regulations. Recorded event data can help the NHTSA meet its responsibility for researching and using appropriate motor vehicle regulations in many ways. Not only will pre-crash data be useful for the Agency's crash avoidance research work, the objective data recorded during a crash will be a major improvement for crash worthiness related activities.

We consider the benefits on-board recorders can provide using the Haddon matrix that divides the crash into three segments and looks at the human, vehicle and environmental conditions of each to be very valuable.

Technology allowing vehicle safety researchers to collect objective data on crashes would open the door to a new generation of understanding. The opportunities are immense since there are approximately 18,000 tow away crashes per day.

Currently the primary metric used to represent crash severity is Delta-V. NHTSA can use the output from on-board data recorders to supplement the Delta-V crash severity estimate currently derived from post crash vehicle inspections. NHTSA sponsored the National Automotive Sampling System (NASS), Special Crash Investigations (SCI) and Crash Injury Research and Engineering Network (CIREN) teams' attempt to make such estimates for all crashes investigated.

About 38 percent of the cases have Delta-V information reported, typically for each vehicle when more than one is involved and for each impact in a multiple impact scenario.

However, the WINSMASH computer algorithm currently used to estimate Delta-V relies primarily on stiffness parameters derived from short duration 35 MPH rigid barrier impact tests. Longer duration real world crashes and less idealized crashes involving yielding fixed and narrow objects, under rides, or multiple impacts are beyond the capabilities of WIN SMASH.

On-board data recorders can provide crash severity for most real world crashes (and confirm WINSMASH results for crashes against unyielding flat barriers) by directly measuring Delta-V.

RETRIEVING DATA FROM GM VEHICLES: GM currently uses a proprietary Event Data Retrieval Unit (EDRU) that interfaces with a standard Tech 1 scan tool to download data through the vehicle diagnostic connector Data can be viewed on the Tech 1 or printed from the EDRU's printer. All data is displayed in a hexadecimal format. For vehicles which sustained electrical system damage, interface cables are provided for powering the system and connecting the SDM directly to the EDRU."

According to Terry, there will be an ample amount of information released sometime in the future regarding the SDM.

Ultimately, I found no intrusion, intentional or otherwise, into any person's privacy via the SDM, "black box." It is not a voice recorder, nor does it record anything other than the specific vehicle's operating system as described. We all want more power and speed, but that however, has to come with additional safety precautions and devices. It is a valuable system and I highly recommend that the SDM system not be tampered with.

And as far as value is concerned, what is the value of your well being and hopefully not, your life and that of other persons who may be passengers such as your wife, children, parent, grandparent or best friend?

If technical service information is needed, the C5 Service Manuals such as the one for '99 alone contains approximately 75 pages about this very subject. It is best to go to the Helm, Inc. "On-Line Bookstore" at: http://www.helminc.com or call 800-782-4356.